

Diesel and various blending nanoparticles based diesel, fuel properties study

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Abstract. In recent years, many researches have been performed to find suitable alternative fuels to petroleum products. In the present investigation, an experimental work has been carried out to examine the fuel properties test for pure diesel, diesel blended with silicon oxide nano, diesel blended with titanium oxide nano and diesel blended with graphene nanoplate which are namely as D, DS5, DT5 and DG5 respectively. The results indicated that the pure diesel fuel density is higher than DT5 by about 1%. However, this value is reduced to about 1% for DG5 and DS5 respectively compared to diesel fuel due to the blending effects. Meanwhile, in calorific value test, DS5 fuel energy content is lower than diesel by about 1.5%. However, this value is reduced to about 1.43% and 1.37% for DG5 and DT5 respectively compared to diesel fuel due to the blending effects.

Keywords. Diesel, Nanoparticle-diesel fuel blends

1. Introduction

The current situation of fossil fuel is very critical, and it is become urgent to look for a suitable alternative due to the continuous increasing demand for these fuels and depleting of their sources. The transportation sector is the primary consumer of these fuels because of the huge number of vehicles that uses in different walks of life [1]. Diesel fuel occupies the larger share of fuel trade in 2010 resulting from the extensive usage of a diesel engine in the different and applications [2]. Furthermore, the usage of fossil fuel can be considered as the main contributor to air pollution and global warming [3]. Diesel engine designed and developed to operate using mineral diesel fuel, therefore, it is important to look for a suitable alternative with similar characteristics to suit the existing diesel engines.

The fuel enrichment method by addition of nano-additives is widely accepted by numerous researchers. The nano-additives are used to achieve specific fuel properties and to improve the performance characteristics and to attain a good emission control of the CI engine without any modification [4]. Nubia et al. Ribeiro [5] summarized the basic necessities of fuel additives added to commercially available diesel



fuels in varying quantities to perform specific functions: (1) the additives should reduce the exhaust emissions, (2) increase the oxygen concentration in the engine and in the particulates filter, (3) improve the fluid stability over a wide-ranging conditions, (4) increase the viscosity index, (5) reduction in ignition delay time, and flash point, (6) the chemical-to-chemical contact should be improved rather than the metal-to-metal contact under high-load conditions to reduce the wear agents that adsorb onto the metal planes.

The advancement in nanotechnology, nanoscience and material technology, has led to expansion of nano-scale particulate matters [6] whose physicochemical properties are relatively diverse with respect to the micron scale elements of the same source material such as larger contact surface area, better stability, fast oxidation, lower melting point, enormous heat of combustion, reduced heat of fusion rate and large heat and mass transfer rates [7]. The fuel modification and revision techniques are extensively known by many investigators to make the specific fuel properties [8]. The effect of the addition of nanoparticles to fluids is investigated in many studies. The high thermal conductivity fluid in engine cooling systems, higher density fuels in propulsion systems, and due to the favorable heat release rate they are used as additives for improvement of the combustion rate of fuels and that adding nanoparticles to a fluid can improve its physical properties, such as thermal conductivity, evaporation rate, shortened delay period and stimulates secondary atomization [9-11].

2. Methodology

2.1. Fuel preparation

The nanoparticles used in this experiment was SiO_2 with size range between 20-30 nm, TiO_2 with size range between 20-30 nm and GNP with size range between 20-30 nm supplied by Sigma-Aldrich Corporation. Figure 1 illustrates the nanoparticles used in this experiment. The nanoparticles were blended into pure diesel with the portion of 5 mg by weight for each nanoparticles using electronic weighing scale. An ultrasonic emulsifier model Hielscher Ultrasonic GmbH UP400S (figure 2) was used to mix the nanoparticles into pure diesel at 60% amplitude and 0.6 seconds cycle for 10 minutes to obtain a well-blended mixture of nanoparticle-biodiesel fuel blends. The test fuel were named as D for pure diesel, DS5 for SiO_2 + pure diesel blend, DT5 for TiO_2 + pure diesel blend and DG5 for GNP + pure diesel blend. Figure 3 illustrates that the condition of mixture of blending before and after using ultrasonic emulsifier. The color of the blend fuel had turned lighter after blended using ultrasonic emulsifier.



Figure 1. a) TiO_2 ; b) GNP; c) SiO_2

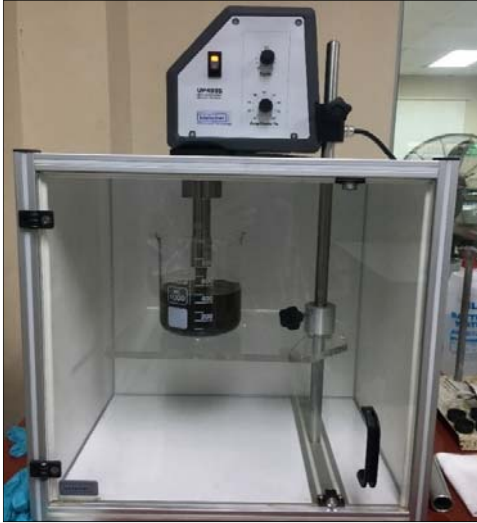


Figure 2. Ultrasonic emulsifier model Hielscher Ultrasonic GmbH UP400S.



Figure 3. Left: before mixing by ultrasonic, right: after mixing by ultrasonic.

2.2. Stability of nanoparticle-diesel fuel blends

Samples of 200 ml for each blend were prepared to observe the fuel blend sedimentation. According to Yu et al. [6], the nanofluids were considered to be stable when the concentration or particle size of suspended nanoparticles remain constant [12]. The sedimentation observation for nanoparticle-diesel fuel blends is shown in figure 4, figure 5(a) and figure 5(b).

Figure 4 illustrates the nanoparticle-diesel fuel blends on Day 1 right after the fuel preparation process was done. It can be observed that TiO_2 blends color quite similar with SiO_2 blends color except for GNP fuel blends, which are darker due to the physical color of GNP. Furthermore, the color of the GNP fuel had turned darker as more CNT were added to the blend. After 2 weeks, the TiO_2 and SiO_2 blends show no significant change in color as shown in figure 5(a). In contrast, GNP agglomerations could be found at the bottom of the sample. After 16 weeks, the TiO_2 and SiO_2 blends still show no significant change in color as shown in figure 5(b) and GNP agglomerations obviously could be found at the bottom of the sample.



Figure 4. Nanoparticle-diesel fuel blends after preparation.

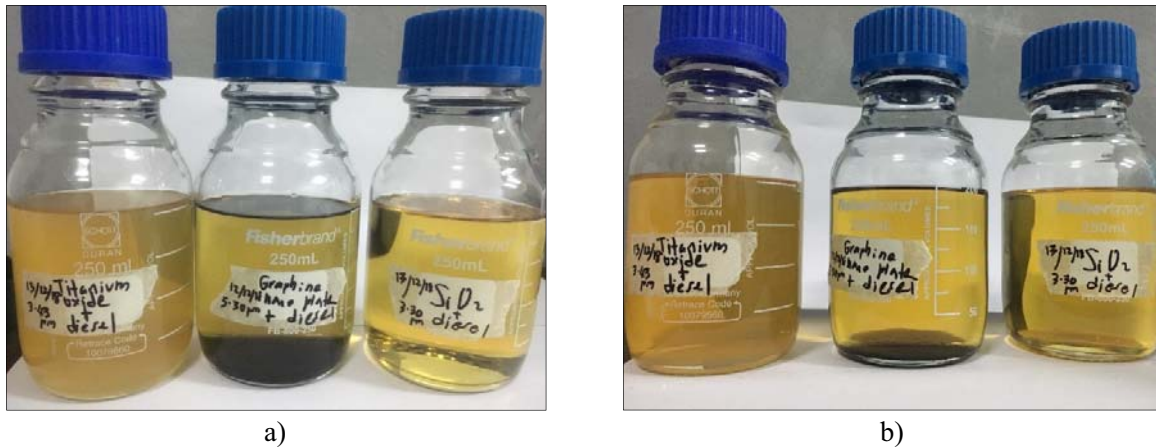


Figure 5. a) Nanoparticle-diesel fuel blends after 2 weeks, b) Nanoparticle-diesel fuel blends after 16 weeks.

2.3. Density test

The measurements were done at 15 °C by using Anton Paar (DMA 35N) density meter. Figs. 6 illustrates the apparatus were involved in density test are glass thermometer, pycnometer, beaker, electronic weighing scale Fisher Scientific B-220C and cold water. The nanoparticle-diesel fuel blends were cooled and the measurements were performed with the glass thermometer when their temperatures reached 15 °C as shown in Fig 7. ASTM D 1298 test method was used to measure nanoparticle-diesel fuel blends. The tested test fuels measured using a portable density/ gravity meter at 15° using B57 type pycnometer which has 26.805 constant value. The measurements were conducted three times for each sample and the results were averaged. The measured mass (figure 8) and calculated density values for each fuel are shown in table 1. The general form of the equation as a function to calculate the density value is given below in equation 1, where weight of empty pycnometer = 19.2706g, Constant volume = 26.805 ml.

$$\rho = \frac{m-W}{V} \tag{1}$$

Where;

ρ (g/ml)= density of fuel

m (g) = mass of pycnometer and fuel

W (g) = weight of empty pycnometer

V (ml) = full volume of pycnometer with any types of fuel

Table 1. Density of tested fuels.

Density Test ASTM D 1298		
Type of fuel	Mass (g)	Density (g/ml)
D	41.6000	0.8300
DS5	41.3140	0.8223
DT5	41.3449	0.8235
DG5	41.3431	0.8234



Figure 6 (a). Electronic weighing scale (Fisher Scientific B-220C).



Figure 6 (b). Pycnometer.



Figure 7. Nanoparticle-diesel blends ASTM D1298.



Figure 8. Mass of pycnometer and nanoparticles-diesel blends.

2.4. Calorific value test

The calorific value the amount of energy content in the fuels which was determined by an oxygen bomb calorimeter model 6772 (Parr instrument company, USA), ASTM D445 (figure 9). The apparatus were involved in calorific value test are puncher, bucket, electronic weighing scale, fuse wire and oxygen bomb calorimeter as shown in Figs. 10. The caloric value of nanoparticles-diesel fuel blends is lower than diesel. Calorific value of each fuel were calculated using equation 2 as shown below. This can be attributed to the calorific value collected for each of the fuel as shown in table 2.

$$H_g = \frac{tW - e_1 - e_2 - e_3}{m} \quad (2)$$

Where;

H_g (MJ/kg) = gross heat of combustion

t (°C) = net corrected temperature rise, $T_{final} - T_{initial}$

W (cal/°C) = energy equivalent of the calorimeter, constant value = 2420 cal/°C

e_1 (cal) = correction for heat of formation of nitric acid

e_2 (cal) = correction for heat of formation of sulfuric acid

e_3 (cal) = correction for heat of formation of the firing wire = 2.3 x (length of fuse wire consumed)

m (g) = mass of the standard benzoic acid sample

Table 2. Calorific value of each tested fuel

Calorific Value Test ASTM D445	
Type of fuel	Calorific Value (MJ/kg)
D	45.0000
DS5	29.9078
DT5	32.9471
DG5	31.3525



Figure 9. Oxygen bomb calorimeter.



Figure 10 (a). Fuse wire.



Figure 10 (b). Puncher.



Figure 10 (c). Mass of Bucket + sample measured by electronic weighing scale.

3. Results and Discussion

Fuel properties are the most important indicator to approve the suitability of individual fuel usage for diesel engine within the fuel standard [5,11]. Therefore, evaluation of fuel properties is very necessary when considering different alternative fuels before operating the engine and analyze the fuel combustion. The fuel property test results for diesel, pure biodiesel (B100) and blended fuel (B20) are shown in table 1 and table 2 together with the standard test method for each property. In general, pure diesel fuel density is highest followed by DT5, DG5 and DS5. Figure 11 shows the effect of nanoparticle-diesel fuel blends on fuel density. It is clearly obvious that pure diesel fuel density is higher than DT5 by about 1%. However, this value is reduced to about 1% for DG5 and DS5 respectively compared to diesel fuel due to the blending effects. The less amount of nanoparticles that use per sample will be effect of fuel properties and it must use several dosage in other for comparison purpose [13]. Calorific value also known as fuel energy content can

be defined as the amount of heating energy liberated by the combustion of a unit value of the fuel. Figure 12 shows the nanoparticle-diesel fuel blends on fuel energy content. It is clearly obvious that DS5 fuel energy content is lower than diesel by about 1.5%. However, this value is reduced to about 1.43% and 1.37% for DG5 and DT5 respectively compared to diesel fuel due to the blending effects. This is due to the fewer amount of nanoparticles that use per sample must use various dosage in other for evaluation purpose.

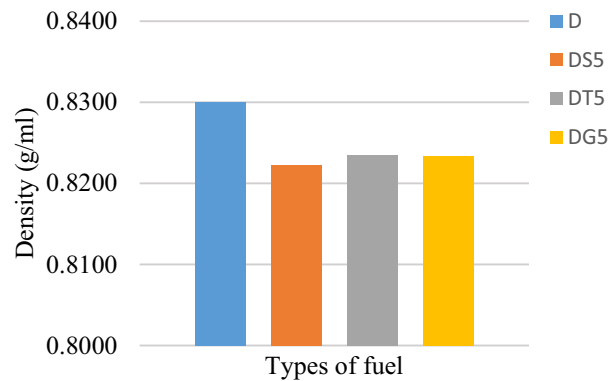


Figure 11. Density for several of fuels.

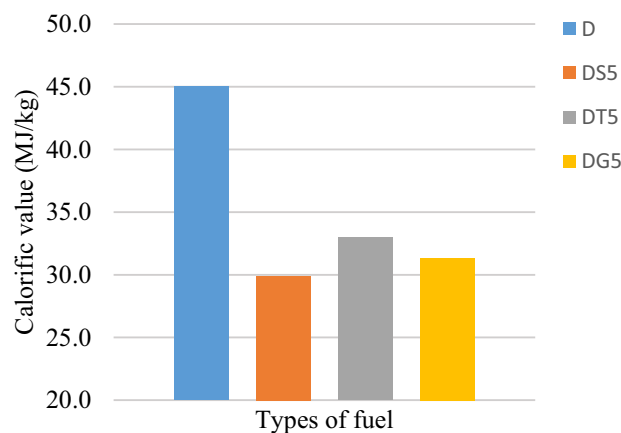


Figure 12. Calorific value for several of fuels.

4. Conclusion

In this study, blended fuel properties were investigated and evaluated compared to blended fuel standard ASTM D1298 and ASTM D445. Fuel property analysis results show that pure diesel highest in terms of fuel density and viscosity and other nanoparticle-diesel fuel blends close to that of diesel fuel. The results obtained from tests are summarized as follows:

- Pure diesel fuel density is higher than DT5 by about 1%. However, this value is reduced to about 1% for DG5 and DS5 respectively compared to diesel fuel due to the blending effects.

- Meanwhile, in calorific value test, DS5 fuel energy content is lower than diesel by about 1.5%. However, this value is reduced to about 1.43% and 1.37% for DG5 and DT5 respectively compared to diesel fuel due to the blending effects.

In a nutshell, the dosage of nanoparticle that use in blending fuel are main important point must highlight. In future, the amount of nanoparticle must be at least 25mg per sample.

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